CHAPTER ONE HUNDRED THIRTEEN

Procedure for Determining Dredging Requirements in Coastal Inlet Channels

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Abstract

In order to assess the technical feasibility of a long term maintenance dredging plan at Oregon Inlet, a simple procedure was devised to evaluate the capabilities of existing ocean going hopper dredges to maintain an ocean entrance channel in an inlet environment characterized by wave climate and resulting influx of littoral material as severe as any Atlantic coast location. The dredging analysis procedure described in this paper was used to evaluate dredge plant capabilities under the operational constraints imposed by depth limitations resulting from the continuous influx of sediment into the project channel, the wave climate, and dredging production capacity in terms of actual hopper capacity and cycle times for different disposal schemes. The shoaling and dredging simulation procedure is described in terms of its application to the proposed navigation project at Oregon Inlet, NC.

Introduction

The natural geometry of an inlet's ebbtide delta or ocean bar is the end product of the integrated effects of tidal currents, wave action and the associated sediment transport and deposition. Of particular concern here is the natural elevation of the ocean bar, which represents both the limiting elevation of sediment accumulation resulting from the influx of littoral materials contributed by the adjacent shores and the level below which littoral sediments will assuredly collect if the ocean bar is entrenched by a navigation channel. In this regard, the rate of sediment accumulation increases with increasing channel depths so that, at some depth, the channel is capable of effecting total interdiction of the sediments entering the inlet environment. Therefore, a rational evaluation of a dredging plan requires establishing the rate of sediment influx to the general inlet environment, the rate of sediment accumulation within the channel at specific depths, and the net rate of sediment removal by a floating

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dredge plant having certain production capabilities. The general procedure described herein develops these factors in terms of daily time periods in order to develop a day-to-day simulation of siltation processes and dredging effects.

Daily Littoral Materials Transport Volumes

The volume of littoral materials transported toward Oregon Inlet on a given day depends on the characteristics of incoming waves occurring on that particular day. The alongshore transport of sediment is a function of the wave height squared, the wave period, and the angle at which waves break relative to the shoreline. However, an adequate estimate of the relative magnitude of alongshore sediment transport can be obtained simply on the basis of wave height squared in accordance with the relationship:

$$Q_i = Q_g \left[\frac{H_i^2}{\sum_{i=1}^{n} H_i^2} \right] \quad (i=1,2,3...n) \qquad (1)$$

where:

i = number of the day during the year

Q_i = littoral transport occurring on day i (cu. yds.)

Q_g = total volume of alongshore sediment transport to the inlet each year (cu. yd s.)

H_i = average wave height for the i^{th} day of the year

n = total number of days during the year (taken as 360 days on the basis of twelve 30-day months)

The total average annual rate at which sand is transported toward Oregon Inlet, Q_g, has been computed as 2,105,000 cu. yds., see reference (1).

Day-to-day variations in the height of the waves required in the above daily transport equation were obtained by analyzing the wave data recorded by the Coastal Engineering Research Center's wave gage at Nags Head between 1963 and 1977. These data were synthesized into the average duration of waves falling within seven wave height classes given in table 1.

Table 1
Wave Height Classes

Wave Height Class	Wave Height Range (ft)	Average Wave Height in Range (ft)
1	$0 \leq H < 1.0$	0.5
2	$1 \leq H < 1.5$	1.3
3	$1.5 \leq H < 2.5$	2.0
4	$2.5 \leq H < 4.0$	3.3
5	$4.0 \leq H < 6.0$	5.0
6	$6.0 \leq H < 10.0$	8.0
7	$10.0 \leq H$	10.0

The probability that waves within each of the seven wave height classes would occur during a given month was obtained by:

$$\left[\text{Probability } H = H_{m,n}\right] = \frac{(\text{Ovbs})_{m,n} \quad (\text{Dura})_{m,n}}{\sum_{m=1}^{7} \sum_{n=1}^{12} \left[(\text{Obvs})_{m,n} \quad (\text{Dura})_{m,n}\right]} \tag{2}$$

where:

m = wave height class (m=1, 2, ...,7)
n = Number of month
$(\text{Obvs})_{m,n}$ = Number of observations of waves within class m during month n
$(\text{Dura})_{m,n}$ = Average duration of waves within class m during month n (in days)

The number of days that a particular wave height class would occur during a given month was computed by multiplying the probability of occurrence of that wave class by the number of days in the month. For simplicity, all months consisted of 30 days, and wave durations were in whole day increments. The end product of the wave data analysis was a wave height-time matrix representing day-to-day variations in wave heights throughout the year, including periods of relatively calm sea conditions and moderate storm events.

Channel Sedimentation

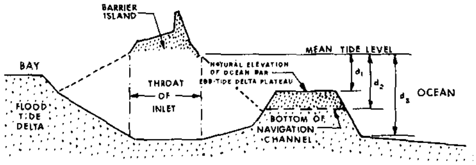
A method developed by Galvin (see reference (2)) was adopted as the means of computing the volume of sediments expected to deposit within a channel of given depth. This method relates the sediment transport potential within the dredged channel to that existing on the ocean bar in its natural state. Galvin developed what is termed the "transport ratio" (equation 3), the ratio of the sediment transport capacity of the dredged channel to that of the natural ocean bar channel.

$$\text{Transport Ratio} = \left(\frac{d_1}{d_2}\right)^{5/2} \tag{3}$$

Galvin defines the predredging depth (d_1) as the minimum controlling depth that exists over the ocean bar prior to any dredging, whereas d_2 is the depth of the dredged bar channel. Both of these depths, which are defined schematically on figure 1, are measured relative to mean tide level (MTL). For the case in which $d_1 = d_2$, no shoaling would occur in the channel; however, if $d_1/d_2 = 0.5$, the transport ratio would equal 0.18, which means that for every 100 cu. yds. of sediment that enters the channel domain, only 18 cu. yds. would be flushed out by the currents, leaving 82 cu. yds. as the volume of deposited material. Since the dredging analysis is concerned with the material that remains in the channel, the sediment retention factor is defined as simply:

$$\text{Sediment Retention Factor} = 1 - \left(\frac{d_1}{d_2}\right)^{5/2} \tag{4}$$

Four hydrographic surveys of the ocean bar of Oregon Inlet made in the 1950's, or prior to the initiation of dredging, were used to determine the natural controlling depth of the bar (d_1) for use in this dredging analysis. The average controlling depth obtained from these four surveys was 9.5 feet MLW or about 10.5 feet MTL.



PROFILE

FIG. 1
DEFINITION SKETCH

On a daily basis, the amount of material that would be retained in the ocean bar channel of the inlet would be:

$$\text{Daily Shoal Volume} = c\, Q_g \frac{H_i^2}{\sum\limits_{i=1}^{360} H_i^2} \left[1 - \left(\frac{d_1}{d_2}\right)^{5/2}\right] \tag{5}$$

where all the terms in this equation have been previously defined except for the factor c which is designated here as the "potential shoaling factor". As stated previously, the rate of sediment accumulation in the bar channel increases with the depth of the cut.

However, until sufficient channel depth is attained to intercept all materials moving into the inlet environment, some material will continue to bypass the inlet via the sloping seaward face of the ocean bar below the bottom of the channel cut. Accordingly, c is defined as the proportion of the gross alongshore transport entering channel, of which a portion is deposited in accordance with the above equation.

In order to assess the magnitude of the potential shoaling factor, a regression analysis was conducted to establish a basic relationship between inlet bar channel siltation and those factors judged to be most influential in the filling and flushing of the channel. Basic data for the analysis was obtained from information available on four unstabilized, dredge-maintained inlet bar-channel projects (including Oregon Inlet) under the jurisdiction of the Wilmington District.

Regression Analysis

Three basic factors were selected as being dominant in terms of influencing the magnitude of shoaling at a particular inlet site having a dredge-maintained ocean bar.

o Ebbtide flow energy is the primary factor acting to flush littoral materials from the inlet environment and, by so doing, serves to maintain the inlet as a viable coastal feature. Its influence in the analysis is represented by the symbol $E_{\Delta T}$, the difference of the mean ebbtide flow energy flux across the ocean bar at its natural elevation and the mean ebbtide flow energy flux through the cross section of the dredged ocean bar channel. It is assumed that the tidal discharge is not significantly altered from one condition to the other. The basic concept reflected in the tidal energy flux difference is that the tidal flow velocities directed seaward over the ocean bar at its natural elevation, in combination with wave agitation, are sufficiently rapid to prevent accumulation of sediments above the natural bar level. Conversely, if a section of the ocean bar is deepened by a navigation channel, the related average local flow velocity is diminished resulting in sediment deposition.

o The magnitude of wave energy reaching the littoral zones adjacent to the inlet is the primary factor controlling the quantity of littoral material moving toward the inlet and, is the fundamental element influencing the shoaling characteristics of an ocean bar navigation channel. In the analysis, the unrefracted wave energy flux per unit width of wave crest offshore of the area of interest, designated E_W, is used as the basic measure of the magnitude of sediment transport toward the inlet.

o The depth of an ocean bar channel determines, in large measure, the degree to which a channel will interdict the littoral sediments entering the inlet environment. In the analysis the measure of sediment entrapment potential, is taken as D_R, the ratio of the depth of the channel to the depth at which the seaward slope of the ocean bar closes or intersects with the sea bottom. Each of these depths is measured from the natural elevation of the ocean bar or ebbtide delta plateau; therefore, the ratio D_R represents the extent to which the ocean bar's seaward slope has been incised by the channel.

The channel sedimentation potential increases or decreases as each of the three factors, $E_{\Delta T}$, E_W, and D_R becomes larger or smaller, respectively. Accordingly, the factors were combined to establish a normalized, independent variable F_I for the regression analysis. The value F_I will be referred to as the "Filling Index" where:

$$F_I = \left(E_{\Delta T} \times E_W \times D_R\right) \div 10^{14} \qquad (6)$$

The denominator 10^{14} is employed so that only the mantissa of the product's true value is used.

A normalized, dependent variable for the analysis was selected as the ratio of the volume of channel filling to the computed volume of the total alongshore sediment influx to the inlet multiplied by 100. This percentage value is referred to as the "volume ratio", V_R and as explained:

$$V_R = \frac{\text{Volume of Channel Sedimentation}}{\text{Volume of Gross Alongshore Sediment Transport}} \qquad (7)$$

The regression analysis was based on data related to four dredge-maintained inlets within the boundaries of the Wilmington District: Oregon, Beaufort, Masonboro (prior to jetty construction) and Lockwoods Folly Inlets. The conditions at these inlets provided for a wide range of F_I and V_R values. Specifically, information available consisted of: (a) measured tidal discharges (Oregon, Beaufort, and Masonboro Inlets) or inlet throat cross sectional areas (Lockwoods Folly Inlet) which permitted tidal discharge computations by means of tidal prism-inlet area relations; (b) site wave statistics representing one or more years of wave gage records; (c) detailed alongshore sediment transport analyses for the shorelines adjacent to each of the inlets; and (d) one or more sets of inlet hydrographic surveys, each consisting of a first and second survey taken at different dates. This permitted measurement of the volume of sediment filling within the navigation channels in the time periods between surveys. The criterion for selection of sequential inlet hydrographic surveys was that the navigation channel in the second survey of any set was in the same location as the channel in the first survey. It could then be assumed that the channel was horizontally stable between surveys and that the only changes occurring were decreases in depth resulting from sediment deposition. From the records of inlet surveys, a total of 12 sets (24 hydrographic surveys) was selected that fulfilled the survey criterion, thus establishing 12 primary data points for the analysis.

For Beaufort Inlet, 10 surveys were used spanning the period February 1964 to May 1974, during which the authorized navigation project depth was 36.5 feet at mean tide level. This provided five data points for channel depths exceeding 36.5 feet at mean tide level. However, an additional data point was developed for

Beaufort Inlet by considering the dredging record for that inlet between 1937 and 1960, during which the authorized project depth was 31.5 feet at mean tide level. This additional data point was based on the average annual sediment volume removed from the ocean entrance channel, the average daily wave energy flux over the year, and an average channel depth of 34.0 feet below mean tide level, assuming that the average depth of the channel between dredging operations was 2.5 feet below authorized project depth. With this additional information, a total of 13 data points was available for analysis.

For each inlet selected, the basic tidal energy parameter, $E_{\Delta T}$, was developed. This parameter defined by equation 8, represents the difference in the daily ebb flow energy flux between the natural and dredged channel condiitons. A detailed development of this parameter is presented in reference (1).

$$E_{\Delta T} = \frac{4T}{3\pi} q^3_{max} \left[\frac{d_2^{\,2} - d_1^{\,2}}{d_1^{\,2} \quad d_2^{\,2}} \right] \qquad (8)$$

where T = Period of tidal wave
q_{max} = maximum instantaneous discharge per unit width of ebb flow area.

The next basic parameter of the independent variable is E_W, the average daily wave energy flux per unit width of wave crest offshore of the site of interest. This parameter represents the intensity of sediment transport from the adjacent beaches to the inlet environment. A basic formulation of wave energy flux can be found in reference (3). Daily wave energy flux can be expressed in a reduced form as:

$$E_W = 1.769 \times 10^6 (H'_o)^2 T \quad \text{ft. lbs.} \qquad (9)$$

where H'_o = Deepwater wave height equivalent to observed shallow water wave unaffected by refraction and friction, given in feet
T = Wave period in seconds

The wave data used for each site had been obtained from nearshore wave recordings near each inlet site.

Throughout the evaluation it was assumed that the wave records represented the average wave climates for the various sites. The average monthly significant wave heights were converted to deep water equivalent wave heights (H_o) based on wave periods, water depths at the respective wave gages, and computed deep water wave lengths (L_o).

The computed daily wave energy flux for each month's average daily deepwater equivalent wave height was multiplied by the number of days in the associated month to arrive at monthly energy flux values. If the quantity of channel fill was being measured, for example, by a first survey dated 15 June and a second survey dated 31 October, the average daily wave energy flux associated with that rate of channel sediment filling was computed as the summation of half of the June energy flux and all the monthly energy values for July, August, September and October, divided by the number of days in the whole period.

The last parameter of the independent variable, the depth ratio, D_R, is a measure of the degree to which channel depths influence the entrapment of sediments. With reference to figure 1, the depth ratio is given as:

$$D_R = \frac{d_2 - d_1}{d_3 - d_1} \tag{10}$$

The dependent variable, V_R, is, as previously defined, the ratio of the volume of channel fill (V_F) to the volume of alongshore sediment. transport (V_{ST}). The volume of fill (V_F) was determined simply by computing the accumulation of channel fill between the first and second hydrographic surveys in each set of surveys. For the additional Beaufort Inlet data point, representing the average conditions in the period 1937-1960, the volume of fill was computed as the average annual volume of material dredged from the inlet entrance channel. The annual alongshore sediment transport volumes for the various sites were available from detailed sediment budget analysis conducted by the Wilmington District. The annual quantities for each site and published references wherein the analyses can be found are as follows: Oregon Inlet - 2.11 million cubic yards, reference (1); Beaufort Inlet - 0.86 million cubic yards, reference (4); Masonboro Inlet - 1.15 million cubic yards, reference (5); and Lockwoods Folly Inlet - 0.60 million cubic yards, reference (6). The independent and dependent variables were computed for each inlet case. The resulting data points are plotted on the diagram shown on figure 2. Tests of several regression equations and related curves revealed that the best fit of the data points was attained by "Hoerl's" special function distribution given in general form by:

$$V_R = aF_I^b \; e^{CF_I} \tag{11}$$

where:

a, b and c are coefficients
V_R = volume ratio
F_I = filling index

In accordance with this generalized form, the regression analysis provided the following relationship:

$$V_R = 10.036686 F_I^{\;-0.000387} e^{0.108489 F_I} \qquad (12)$$

which is valid for F_I values equal to or greater than 2 and has the curvilinear form shown on figure 2.

In order to display the expected channel sediment filling in a dredge-maintained navigation channel through the ocean bar at Oregon Inlet, the regression equation was solved for filling index, F_I, values corresponding to various channel depths. Channel low water depths corresponding to the F_I scale are shown along the bottom of figure 2. The daily deepwater equivalent wave energy flux used to compute the F_I values was derived from a nearshore wave height and period of 3.0 feet and 8.6 seconds, respectively. These represent the mean significant wave characteristics synthesized from the record of wave measurements by a gage located in a water depth of 17 feet at Nags Head, N.C., over the period July 1964 - April 1976. In reference to figure 2, it is readily evident that ocean bar channel depths in Oregon Inlet at and below the authorized channel depths of 20 feet MLW datum have corresponding F_I values well within the domain of 100 percent entrapment of the alongshore sediment transport from the adjacent beaches.

The results of the regression analysis would fully justify adopting a c factor of 1.0 for the "Daily Shoal Volume" equation selected for the dredging analysis.

In the case of Oregon Inlet, the shoaling dredging simulation was run using C values of 0.5, 0.75, and 1.0 in order to determine the sensitivity of the basic procedure with respect to the magnitude

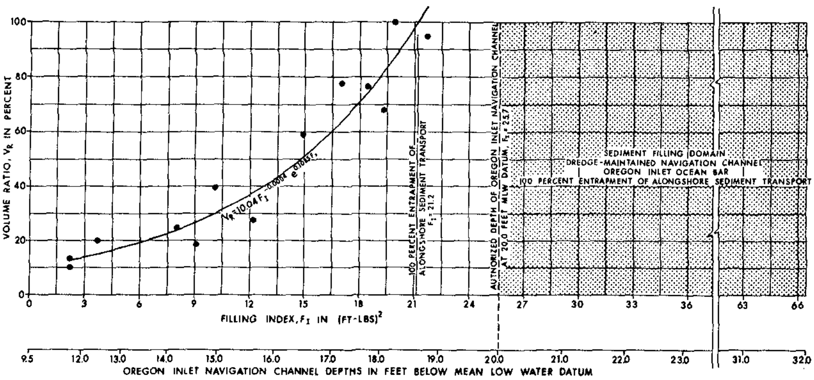


FIGURE 2

REGRESSION ANALYSIS
CHANNEL DEPTH-SEDIMENT FILLING RELATIONSHIPS
DREDGE-MAINTAINED NAVIGATION CHANNEL
OREGON INLET OCEAN BAR

of dredging resulting from the analysis. In all cases, the results indicated that an intensive dredging effort would be required to maintain the project channel dimensions requiring a channel having a width of 400 feet and a depth of 20 feet below MLW. It was decided to perform the dredging analyses for Oregon Inlet with a c factor of 0.75. This provided a degree of conservability in the analysis and recognized that there were other processes not accounted for that could cause some increased tidal flushing of the channel.

Verification of the Shoaling Rate Simulation Procedure

The method adopted for computing shoaling in the ocean bar channel was compared to actual shoaling rates experienced following eight maintenance dredging operations at Oregon Inlet by the U.S. Hopper Dredge HYDE. The eight shoaling episodes are designated by the letters A through H on figure 3. Controlling depths, rather than average depths were used in the comparison during the time in which the HYDE was employed at Oregon Inlet. Since the computational method utilizes average depths in the channel, the computed and controlling depths are not comparable on a one-to-one basis. However, the rate of change in the controlling depths is directly related to the rate of change in the average depths.

Controlling depths in the ocean bar channel immediately after each dredging operation ranged from about 14.5 and 18.8 feet below MLW, whereas depths at the end of each shoaling episode varied between 7.2 and 10.3 feet below MLW. The average controlling depth in the channel during the shoaling episodes was 12.8 feet below MLW computed by averaging the after-dredging and end-of-episode controlling depths. Since the average controlling depth was only 3.3 feet below the average natural elevation of the ocean bar (9.5

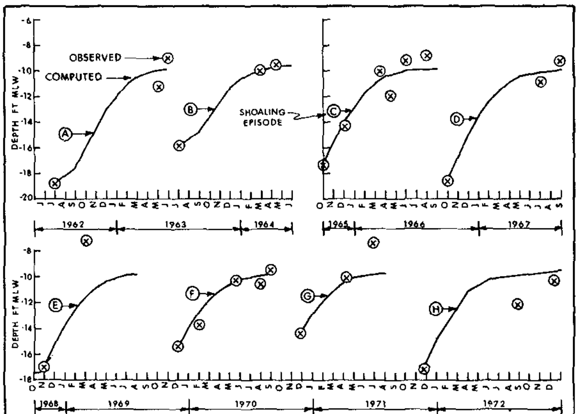


FIG. 3
COMPARISON OF COMPUTED VERSUS OBSERVED DEPTH CHANGES IN THE OREGON INLET OCEAN BAR CHANNEL FOLLOWING MAINTENANCE DREDGING BY THE U.S. HOPPER DREDGE HYDE

feet below MLW), the proportion of total littoral drift entering the channel domain would be small in comparison to conditions under which minimal depths of 20 feet below MLW would be permitted. In reference to the line of regression displayed on figure 2, channel depths of 12 to 13 feet below MLW would result in volume ratios, V_R, of 13 to 17 percent. With reference to figure 3, it is evident that, in general, depths less than the average of 12.8 feet existed for longer periods of time than the depths which were greater than average. Therefore, a volume ratio V_R amounting to about 13 percent was selected as being representative of the past conditions. On the basis of this, the potential shoaling factor c, adopted for the verification procedure, was 0.25.

Dredging Simulation

Removal of sediment from the inlet ocean bar channel by dredging is represented in the procedure by a daily dredging production rate. The production rate is the volume of material that can be removed from the channel during a single working day. This daily volume is the product of the effective hopper capacity for the dredge being evaluated and the number of dredging and disposal cycles that can be accomplished during a working day. A single dredging and disposal cycle time is determined by:

$$\text{Cycle Time} = \text{Dredging Time} + \text{Haul Time} + \text{Disposal Time} + \text{Return Time} + \text{Turning Time}$$

These times are determined by the operational and physical characteristics of the dredge vessel: the light and loaded speeds and the hopper capacity and filling rate.

In the procedure, a dredge is said to operate on a given day if sufficient depth exist in the channel for safe operations, the wave heights do not exceed allowable levels, and operational and maintenance schedules are met. The safe operating depth is defined by:

$$\text{Safe Operating Depth} = \text{Loaded Vessel Draft} + 1.2\ H \qquad (13)$$

where H is the wave height as previously defined. The vessel draft is the actual loaded draft plus a margin of safety of 1-1/2 to 3 feet. Half the wave height is added to allow for vessel motions when underway.

Wave height limitations were determined through discussions with vessel captains and by comparison of dredge logs and wave records for the Corps of Engineers dredge HYDE and the Gulf Coast Trailing Company dredge MERMENTAU. The HYDE performed channel maintenance dredging during the period 1962 to 1971. Comparison of daily operating logs to wave data collected at the Nags Head Pier, located approximately 25 miles north of Oregon Inlet, showed that when wave heights reached or exceeded 4.0 feet, the HYDE did not operate. Comparison of wave records from the Field Research Facility at Duck, NC, located approximately 60 miles north of Oregon Inlet, and operating records of the MERMENTAU operating at the inlet in 1983, showed the operations were terminated when wave heights exceeded 3.5 feet at Duck. These limiting wave height values were used as a guide in establishing limitations for other dredge vessels considered in dredging studies at Oregon Inlet.

In studies of dredging feasibility at Oregon Inlet, intensive dredging and disposal operations with continuous operations 21 hours per day and 7 days per week were evaluated. In order to account for dredge vessel down time required for scheduled and unscheduled maintenance and taking on fuel, water and provisions, dredging operations were permitted 6 out of 7 days. Together with down time due to wave conditions the average down time per month averaged about 20 percent. This agrees with down time experienced by MERMENTAU operations in Oregon Inlet in 1983.

Dredging Shoaling Evaluation Procedure

The depth computed by the shoaling - dredging simulation is the net result of shoaling and dredging in the inlet channel. It is assumed that depth changes occur uniformly over the length and width of the channel. Channel length is measured between the 20 foot contours inside and outside the inlet. Channel width and depth are specified project dimensions. In the case of Oregon Inlet the project channel depth and width were 20 feet and 400 feet respectively. The measured channel length was 3,280 feet. From the daily variation of channel depths provided by the shoaling and dredging simulation, monthly minimum and maximum depths are taken to obtain a time history of monthly channel depth variation over the period of analysis.

The simulation also provides an accounting of simulated dredging operations in terms of the number of days per month the dredge operates, the number of dredging days lost due to weather (waves), and quantities of material dredged in cubic yards.

Several alternative dredging schemes for maintenance of an ocean entrance channel at Oregon Inlet were evaluated using the dredging and shoaling simulation. The various schemes varied in terms of the method of disposal and type of dredge vessel considered.

The first alternative considered involved dredging of the channel by trailer suction hopper dredge and pumping the dredged material to adjacent beaches much like conventional beach nourishment techniques. The direct pumpout scheme was evaluated for three different floating dredge plants representing a range of capacities and vessel drafts. Two Corps of Engineers dredges and a class of privately owned split hull hopper dredges with direct pumpout capabilities were evaluated. The shoaling and dredging simulation was applied to evaluate the capabilities and efficiency of each plant to maintain the project channel at Oregon Inlet. Evaluated were the Corps dredge MARKHAM, a medium sized hopper dredge with a total bin capacity of 2,000 cubic yards and a loaded draft of 23 feet; the Corps dredge HAINS with a total bin capacity of 330 cubic yards and a loaded draft of 13 feet; and the split hull hopper dredge ATCHAFALAYA operated by Gulf Coast Trailing Company with a total bin capacity of 1,000 cubic yards and a loaded draft of 14.5 feet.

Dredging cycle times were determined by:

$$\text{Direct Pumpout Cycle Time} = \text{Dredging Time} + \text{Haul Time} + \text{Hookup and Pumpout Time} + \text{Return Time} + \text{Turning Time}$$

Production rates were based on a working day of 21 hours, a 26 day working month, and wave height limitations of 5 feet for the MARKHAM and ATCHAFALAYA and 4 feet for the HAINS. It was assumed that sufficient initial channel depths existed in the bar channel to allow for safe operations of each dredge at the initiation of maintenance dredging operations. In each case, maintenance dredging was assumed to begin in September, the beginning of the period of highest wave energy and associated alongshore transport to Oregon Inlet. The basic results of the analyses of the various dredges is presented below as an example of the application of the shoaling and dredging simulation procedure.

The production rate of the HAINS, when utilizing the direct pumpout technique is 3,980 cubic yards/day. The average daily influx of sediment to the channel, assuming that only 75 percent of the total littoral drfit reaches the channel domain, is 4,330 cubic yards/day. Though the shoaling-dredging simulation accounts for a portion of the daily sediment influx being flushed from the channel by ebb tide currents, the number of days during the year that the HAINS could not work in the inlet due to normal downtime or inclement conditions would make it impossible for this particular dredge to maintain the channel below 20 feet MLW using direct pumpout. In evaluating the HAINS for direct pumpout, initial channel depths of 24 to 28 feet MLW were considered. However, even with the initial depth of 28 feet MLW, the depth in the channel decreased to slightly less than 20 feet MLW by the end of the first year of dredging. With the HAINS continuing to operate at its maximum rate into the second year, the shoaling-dredging simulation predicted that the channel depth would decrease to less than the 15-foot MLW maximum safe operating depth for the HAINS by January. The time variations of the computed minimum and maximum monthly depths in the Oregon Inlet ocean bar channel during direct pumpout maintenance dredging operations by the HAINS are shown on figure 4.

The direct pumpout capacity of the MARKHAM is 14,000 cubic yards/day which is more than three times the average daily influx of sediment to the channel; therefore the MARKHAM would not have to be committed to Oregon Inlet on a year-round basis. However, the channel developed by the MARKHAM at the end of an operation

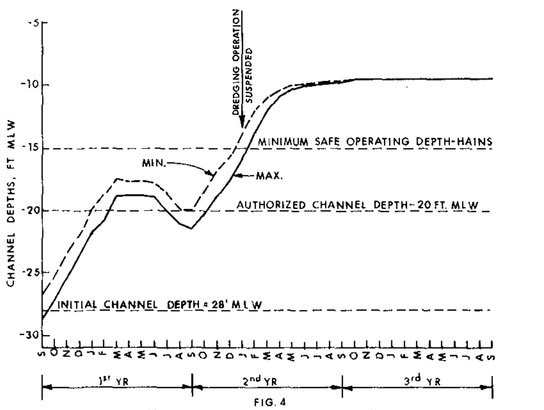


FIG. 4
COMPUTED MONTHLY MAXIMUM AND MINIMUM OCEAN BAR CHANNEL DEPTHS DURING 3 YR SIMULATION OF MAINTENANCE DREDGING BY THE HAINS USING DIRECT PUMPOUT

would have to be of sufficient depth to store materials depositing in the channel during nondredging months to a depth at or below 24 feet MLW. Otherwise, a dredge of smaller dredge of shallower draft would have to be used to reestablish the 24-foot MLW depth required by the MARKHAM on its return to the project site.

Though the MARKHAM is capable of dredging to a maximum depth of 45 feet, the practical limit on the dredge of the inlet channel was set at 32 feet MLW or slightly below the toe of the seaward slope of the ocean bar at Oregon Inlet. In evaluating the MARKHAM, various limits were set on the number of months that the dredge would work in Oregon Inlet and on the maximum depth that the dredge would be allowed to cut into the bar. The number of months ranged from 4 to 8, whereas the maximum channel depths considered were 28, 30, and 32 feet MLW. A total of 15 combinations of dredge time and maximum depth were considered. Of the 15 alternatives tested, only two yielded predicted channel depths greater than 24 feet MLW at the end of the 12-month evaluation period. An alternative involving a 7-month commitment of the MARKHAM to Oregon Inlet and a maximum channel depth of 32 feet MLW was selected for the purpose of comparison with other alternative schemes.

The selected maintenance dredging operation for the MARKHAM was simulated over a 3-year period to determine if the dredge would be able to maintain adequate depths over an extended period of time. A plot of the monthly maximum and minimum channel depths for this 3-year simulation is given on figure 5. The depths for a particular month remained fairly constant from year to year, and the channel depth never decreased to less than 24 feet MLW. Thus, it is evident that the MARKHAM could, without difficulty, maintain the Oregon Inlet ocean bar channel using direct pumpout.

The evaluation of the ATCHATALAYA, which has a direct pumpout production rate of 5,900 cu. yds./day, considered five initial depths in the bar channel, namely 20, 24, 26, 28, and 30 feet MLW. Plots of the minimum monthly depths in the inlet channel for each of the five initial depths considered for the ATCHAFALAYA are shown on figure 6. For the 20-foot MLW initial depth, there was not a sufficient depth buffer in the channel to accomodate the difference between the rate of shoaling and dredging that would occur between September and January. Consequently the depth in the channel decreases below the 16-foot MLW safe operating depth for the ATCHAFALAYA. This would result in a cessation of the dredging activity in January. With an initial depth of 24 feet MLW, the ATCHAFALAYA was able to work in the bar channel throughout the year; however, the minimum depth in the channel did decrease to slightly less than 20 feet MLW during the months of January through April. For all the other initial depths considered, i.e., 26, 28, and 30 feet MLW, the shoaling-dredging simulation indicated that the ATCHAFALAYA would be able to maintain channel depths deeper than 20 feet MLW throughout the year. Additionally, the depth in the channel at the end of the yearly dredge cycle was slightly deeper than at the beginning for initial depths of 26 and 28 feet MLW; therefore, during normal littoral transport years the ATCHAFALAYA would be able to maintain the 20-foot MLW bar channel from year to year. Since all of the initial channel depths equal to or greater than 26 feet MLW resulted in acceptable channel depths during the year, the 26-foot MLW initial channel depth was selected.

Summary

The procedure discussed in this paper provides a simple method for evaluating the capabilities of different dredge plants for maintaining a channel through the ebb tidal bar of Oregon Inlet, NC. The information required for its application includes the natural controlling depth of the ocean bar, the project channel width and length, the dredge plant capacities and operational characteristics, and a wave record covering the period of analysis.

The results of the procedure provide a time history of channel depths over the period of analysis and a means of evaluating the efficiency of a given dredge plant operating in the inlet. A dredging plan can be optimized by varying the length of the dredging period and the initial channel depths.

Acknowledgements

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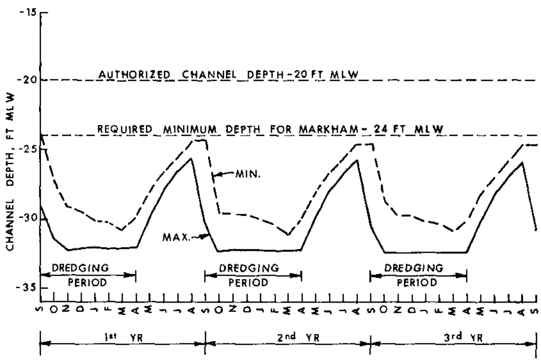

FIG. 5
COMPUTED MONTHLY MAXIMUM AND MINIMUM OCEAN BAR CHANNEL DEPTHS DURING 3 YR SIMULATION OF MAINTENANCE DREDGING BY THE MARKHAM USING DIRECT PUMPOUT

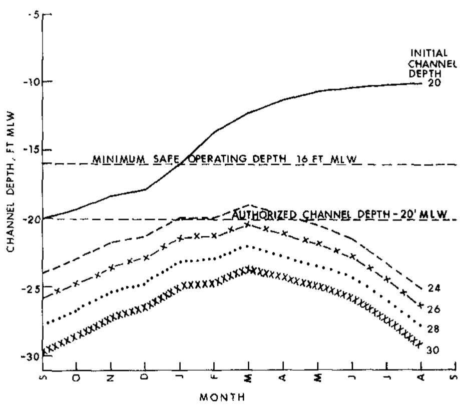

FIG. 6
DREDGE ATCHAFALAYA DIRECT PUMPOUT- MONTHLY MIN. OCEAN BAR CHANNEL DEPTHS FOR VARIOUS INITIAL CHANNEL DEPTHS

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